

76  
**N90-10092**

**A Comparison of Software for the Modeling and  
Control of Flexible Systems**

**Lawrence W. Taylor, Jr.  
NASA Langley Research Center**

**Computational Aspects Workshop  
July 12-14, 1988 Williamsburg, VA**



Memorandum

To: Whom it may concern

From: 161/Chief Scientist, GCD

Subject: Development of Software for the Control of Flexible Systems

*A summary program*

I propose a cooperative effort among specialists who use or develop software for simulating and analyzing the control of flexible, aerospace systems. A comparison of existing software for modeling control systems and flexible structures, applied to several example problems would be quite valuable. The comparison would indicate computational efficiency and capabilities with respect to handling nonlinearities and graphical output.

Because of the diversity of applications of such software, I believe that the proposed cooperative effort can transcend projects involving specific applications. Comparisons of software capability and efficiency can be made and gaps can be identified. In this way the results of the cooperative effort can provide guidance for individual projects.

Enclosed are several charts which outline the objectives and approach of the proposed cooperative effort. I would appreciate your suggestions and expressions of interest in this matter.

*See 161-100-100*  
Sincerely,

*117*  
*Lawrence W. Taylor, Jr.*

Lawrence W. Taylor, Jr.  
Mail Stop 161  
NASA Langley Research Center  
Hampton, VA 23665  
(804)-865-4591

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## OBJECTIVE

**"To Evaluate Software for the Control, Analysis, Simulation and Design of Flexible Aerospace Systems....**

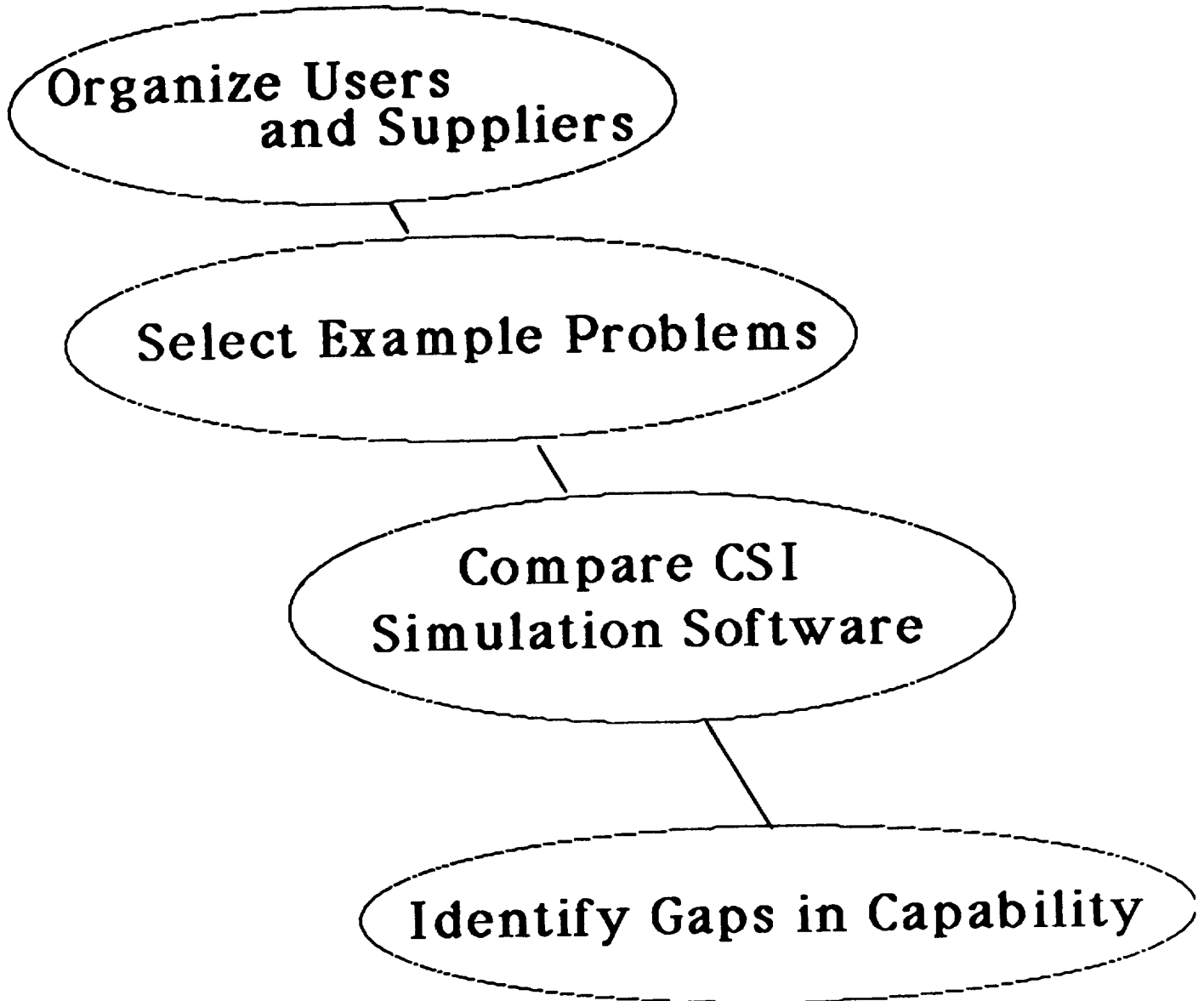
**Which includes:**

- **Control Law Dynamics**
- **Actuator/Sensor Dynamics**
- **Structural Dynamics**

**And Which is Efficient and Accurate**

**And Which is Easy to Use."**

## **APPROACH**

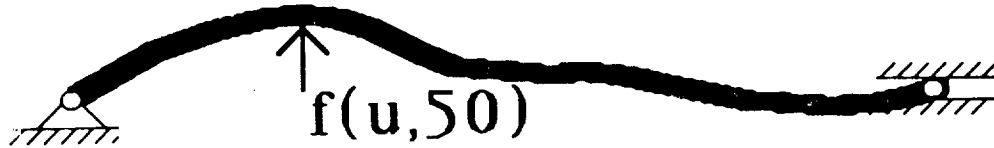


## **Example Problems**

- **Uniform Beam - Pinned-Pinned**
- **SCOLE (L. Taylor-LaRC)**
- **Translation/Rotation/Flex (Juang-LaRC)**
- **SAFE(70% Deployment)(L. Taylor-LaRC)**
- **Pinhole Occulter (Henry Waites-MSFC)**
- **Manned Space Station**
  - a. Reboost**
  - b. Solar Dynamic Pointing**
  - c. MRMS Operation**
  - d. Docking**

**Others?**

## Pinned-Pinned Beam



$$m\ddot{u} + c|\dot{u}''|\dot{u}'' + EIu'''' = 0$$

$$u(x,0) = A\sin(\pi x/L)$$

$$A = 1.3 \text{ Ft.}$$

$$L = 130 \text{ Ft.}$$

$$EI = 40,000,000 \text{ Lb/Ft}^2$$

$$m = .09556 \text{ Slugs/Ft}$$

$$c = 280.32$$

$$f_{50}(s) = \frac{K\dot{u}(50,s)}{(1 + Ts)}$$

$$K = -.5$$

$$T = .2 \text{ Sec}$$

### Problem:

1. Calculate Time History of  $u(65,t)$   $0 < t < 5.26$
2. Plot Time History
3. Calculate Modal Characteristics  $1 < k < 10$
4. Express Final Shape in Modal Coordinates

## CSI Simulation Software

- NASTRAN
- DISCOS
- TREETOPS(CONTOPS)
- EAL
- LATDYN
- DADS
- Multi-MACS
- ORACLS
- EISPAC
- LINPAC
- Matrix<sub>x</sub>
- CTRL-C
- SYSPAC



# Information Sheet

NAME of SOFTWARE: DISCOS

RESPONSIBLE PERSON: Harry Frisch  
NASA Goddard Space Center  
Bldg. 11, Rm. S221A  
Greenbelt, MD 20771

## CAPABILITIES:

- |  |   |  |       |
|--|---|--|-------|
| 1. Nonlinear Kinematics?                     | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | _____ |
| 2. Finite Element Modeling?                  | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | _____ |
| 3. All Rotational and Translational D.O.F.?  | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | _____ |
| 4. Linked to Distributed Parameters?         | Yes <input type="checkbox"/>            | No <input type="checkbox"/>            | _____ |
| 5. Large Amplitudes?                         | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | _____ |
| 6. Nonlinear Damping?                        | Yes <input type="checkbox"/>            | No <input checked="" type="checkbox"/> | _____ |
| 7. Control Law Dynamics?                     | Yes <input type="checkbox"/>            | No <input checked="" type="checkbox"/> | _____ |
| 8. Sensors and Actuator Dynamics?            | Yes <input type="checkbox"/>            | No <input checked="" type="checkbox"/> | _____ |
| 9. Nonlinear Joints?                         | Yes <input type="checkbox"/>            | No <input checked="" type="checkbox"/> | _____ |
| 10. Distributed Parameter System?            | Yes <input type="checkbox"/>            | No <input checked="" type="checkbox"/> | _____ |
| 11. Optimal Control Synthesis?               | Yes <input type="checkbox"/>            | No <input checked="" type="checkbox"/> | _____ |
| 12. Sensitivity Functions for P.E. & Design? | Yes <input type="checkbox"/>            | No <input checked="" type="checkbox"/> | _____ |

DOCUMENTATION: Complete. \_\_\_\_\_

SIZE: 500K \_\_\_\_\_

LANGUAGE: Fortran 77 + \_\_\_\_\_

INTERACTIVE: No. \_\_\_\_\_

GRAPHICS: Plots \_\_\_\_\_

AVAILABILITY: Free, Nonproprietary \_\_\_\_\_

## Information Sheet

**NAME of SOFTWARE:** LATDYN

**RESPONSIBLE PERSON:** Jerry Housner  
Mail Stop - 230  
NASA Langley Research Center  
Hampton, VA 23665

**CAPABILITIES:**

- |  |   |  |          |
|--|---|--|----------|
| 1. Nonlinear Kinematics?                     | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | 2-D.O.F. |
| 2. Finite Element Modeling?                  | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | 2-D.O.F. |
| 3. All Rotational and Translational D.O.F.?  | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | 2-D.O.F. |
| 4. Linked to Distributed Parameters?         | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | 2-D.O.F. |
| 5. Large Amplitudes?                         | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | 2-D.O.F. |
| 6. Nonlinear Damping?                        | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | Add Code |
| 7. Control Law Dynamics?                     | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | Add Code |
| 8. Sensors and Actuator Dynamics?            | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | Add Code |
| 9. Nonlinear Joints?                         | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | Add Code |
| 10. Distributed Parameter System?            | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | 2-D.O.F. |
| 11. Optimal Control Synthesis?               | Yes <input type="checkbox"/>            | No <input checked="" type="checkbox"/> |          |
| 12. Sensitivity Functions for P.E. & Design? | Yes <input type="checkbox"/>            | No <input checked="" type="checkbox"/> |          |

**DOCUMENTATION:** 2-D.O.F. Written, 3-D.O.F. Under Development

**SIZE:** 400K

**LANGUAGE:** Fortran 77

**INTERACTIVE:** Yes

**GRAPHICS:** Time Histories, Line Drawing, PSD, Movies

**AVAILABILITY:** Free, Nonproprietary

## Information Sheet

**NAME:** Multibody Analysis & Control Synthesis (MACS)

**RESPONSIBLE PERSON:** Lawrence W. Taylor  
NASA Langley Research Center  
Hampton, VA 23665  
(804)-865-4591

### **CAPABILITIES:**

- |   |   |  |         |
|---|---|--|---------|
| 1. Nonlinear Kinematics?                    | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | _____   |
| 2. Finite Element Modeling?                 | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | _____   |
| 3. All Rotational and Translational D.O.F.? | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | _____   |
| 4. Linked to Distributed Parameters?        | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | _____   |
| 5. Large Amplitudes?                        | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | _____   |
| 6. Nonlinear Damping?                       | Yes <input type="checkbox"/>            | No <input checked="" type="checkbox"/> | Not Yet |
| 7. Control Law Dynamics?                    | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | _____   |
| 8. Sensors and Actuator Dynamics?           | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | _____   |
| 9. Nonlinear Joints?                        | Yes <input type="checkbox"/>            | No <input checked="" type="checkbox"/> | Not Yet |
| 10. Distributed Parameter System?           | Yes <input type="checkbox"/>            | No <input checked="" type="checkbox"/> | _____   |
| 11. Optimal Control Synthesis?              | Yes <input type="checkbox"/>            | No <input checked="" type="checkbox"/> | _____   |

**DOCUMENTATION:** Incomplete

**SIZE:** 25K Core Memory

**LANGUAGE:** FORTRAN 77

**INTERACTIVE:** No

**GRAPHICS:** None

**AVAILABILITY:** No Charge

## Information Sheet

**NAME of SOFTWARE:** TREETOPS (CONTOPS)

**RESPONSIBLE PERSON:** Ramen Singh  
Dynacs Engineering Company  
2280 U.S. 19 No., Suite 111  
Clearwater, FL 34623

### **CAPABILITIES:**

- |  |   |  |       |
|--|---|--|-------|
| 1. Nonlinear Kinematics?                     | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | _____ |
| 2. Finite Element Modeling?                  | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | _____ |
| 3. All Rotational and Translational D.O.F.?  | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | _____ |
| 4. Linked to Distributed Parameters?         | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | _____ |
| 5. Large Amplitudes?                         | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | _____ |
| 6. Nonlinear Damping?                        | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | _____ |
| 7. Control Law Dynamics?                     | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | _____ |
| 8. Sensors and Actuator Dynamics?            | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | _____ |
| 9. Nonlinear Joints?                         | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | _____ |
| 10. Distributed Parameter System?            | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>            | _____ |
| 11. Optimal Control Synthesis?               | Yes <input type="checkbox"/>            | No <input checked="" type="checkbox"/> | _____ |
| 12. Sensitivity Functions for P.E. & Design? | Yes <input type="checkbox"/>            | No <input checked="" type="checkbox"/> | _____ |

**DOCUMENTATION:** Complete. Course Available.

**SIZE:** 600K

**LANGUAGE:** Fortran 77 +

**INTERACTIVE:** Yes. Sun, MicroVAX, Masscomp

**GRAPHICS:** Plots, Windows, Movies

**AVAILABILITY:** Free, Nonpropriety

# Information Sheet

**NAME of SOFTWARE:** \_\_\_\_\_

**RESPONSIBLE PERSON:** \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

## **CAPABILITIES:**

- |  |  |
|--|--|
| 1. Nonlinear Kinematics?                     | Yes <input type="checkbox"/> No <input type="checkbox"/> _____ |
| 2. Finite Element Modeling?                  | Yes <input type="checkbox"/> No <input type="checkbox"/> _____ |
| 3. All Rotational and Translational D.O.F.?  | Yes <input type="checkbox"/> No <input type="checkbox"/> _____ |
| 4. Linked to Distributed Parameters?         | Yes <input type="checkbox"/> No <input type="checkbox"/> _____ |
| 5. Large Amplitudes?                         | Yes <input type="checkbox"/> No <input type="checkbox"/> _____ |
| 6. Nonlinear Damping?                        | Yes <input type="checkbox"/> No <input type="checkbox"/> _____ |
| 7. Control Law Dynamics?                     | Yes <input type="checkbox"/> No <input type="checkbox"/> _____ |
| 8. Sensors and Actuator Dynamics?            | Yes <input type="checkbox"/> No <input type="checkbox"/> _____ |
| 9. Nonlinear Joints?                         | Yes <input type="checkbox"/> No <input type="checkbox"/> _____ |
| 10. Distributed Parameter System?            | Yes <input type="checkbox"/> No <input type="checkbox"/> _____ |
| 11. Optimal Control Synthesis?               | Yes <input type="checkbox"/> No <input type="checkbox"/> _____ |
| 12. Sensitivity Functions for P.E. & Design? | Yes <input type="checkbox"/> No <input type="checkbox"/> _____ |

**DOCUMENTATION:** \_\_\_\_\_

**SIZE:** \_\_\_\_\_

**LANGUAGE:** \_\_\_\_\_

**INTERACTIVE:** \_\_\_\_\_

**GRAPHICS:** \_\_\_\_\_

**AVAILABILITY:** \_\_\_\_\_

## Solution Characteristics

- Time Required - CPU Sec.
- Accuracy
  - a. Modal Characteristics
  - b. Time Histories (PSD)
- Memory Required
- Input
- Output

## **PANEL DISCUSSION**

1. Should We Compare Software for  
Control/Modeling?
2. Should We Establish Example Problems?
3. Should This Workshop be Repeated?  
.....Changed?  
.....Merged?





**SESSION III - COMPUTATIONS EFFICIENCY AND CAPABILITY**

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281

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